PROXIMATE, MINERAL, FATTY ACID COMPOSITION AND QUALITY OF THE OIL OBTAINED FROM LANDRACE AND IMPROVED SESAME (*Sesamum indicum*) SEEDS GROWN IN NORTHERN UGANDA

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A DISSERTATION SUBMITTED TO THE DIRECTORATE OF RESEARCH AND GRADUATE TRAINING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN FOOD TECHNOLOGY OF KYAMBOGO UNIVERSITY

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DECLARATION

I, Lydia Nayiga, declare that the dissertation I hereby submit for the award of the Degree of Master of Science in Food Technology of Kyambogo University, is entirely mine and has not been presented for any award at this or any other university or higher institution of learning.

Signature……………………………………… Date…………………………………………

APPROVAL

This is to certify that Lydia Nayiga conducted a study titled "Proximate, mineral, fatty acid composition and quality of the oil obtained from Landrace and improved sesame (*Sesamum Indicum*) seeds grown in Northern Uganda" under our supervision. We approve the submission of this dissertation.

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DEDICATION

To my family

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TABLE OF CONTENTS

LIST OF TABLES

ABBREVIATIONS/ ACRYNOMS

FAO	Food and Agriculture Organisation
WHO	World Health Organisation
CODEX	Codex Alimentarious Commission
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
NaSARRI	National Semi Arid Resources Research Institute
UFA	Unsaturated Fatty Acids
SFA	Saturated Fatty Acids
PUFA	Polyunsaturated Fatty Acids
MUFA	Monounsaturated Fatty acids
RDA	Recommended Dietary Allowance
N	Normality
M	Molarity
SD	Standard Deviation
ND	Not Detected
FAME	Fatty Acid Methyl Esters
GC-FID	Gas-Chromatography - Flame Ionization Detector

ABSTRACT

Uganda is the seventh sesame-producing country in Africa and ninth in the world. Sesame is a non-traditional cash crop with tremendous export potential. Data on composition of sesame in Uganda is scarce, making the planning of the sesame value chain a challenge**.** Landraces (*Ajimo*, *Otara*, *Arut*) and improved sesame seeds (Sesim I, Sesim II and Sesim III) were obtained from MAAIF Vegetable Oil Development Project (VODP-Phase 2) and NaSARRI, respectively. Proximate composition was determined using methods of the Association of Official Analytical Chemists (AOAC). Fatty acids (FA) were determined as FAME using GC-FID. Minerals were determined using Atomic Absorption Spectrophotometry (AAS). Quality parameters; refractive index (RI), acid value (AV), peroxide value (PV), and iodine value (IV) of oil extracted from sesame seeds were determined by AOAC and the American Oil Chemists Society (AOCS) methods. Findings from the study showed a significant difference in moisture, fat, protein, crude fibre, crude ash and carbohydrates between the landrace and improved seeds. FA composition was variable between landraces and improved sesame seeds. The major FA of sesame oil were oleic acid (18:1ω9), linoleic acid (18:2ω6), palmitic acid (16:0) and stearic acid (18:0). Unsaturated FA predominated over the SFA. Landraces had a higher content of 18:2ω6 than the improved sesame seeds while improved sesame seeds had higher amounts of 18:1ω9. Mineral concentrations varied from 521.45 to 665.15 mg/100 g for P, 315.70 to 458.22 mg/100 g for K, 199.60 to 363.16 mg/100 g for Mg, 69.29 to 83.15 mg/100 g for Na, 50.42 to 56.40 mg/100 g for Ca, 2.32 to 2.86 mg/100 g for Fe, 1.12 to 2.77 mg/100 g for Zn and 1.13 to 1.59 mg/100 g for Cu. Oil quality parameters were within the international standards for oils meant for human consumption. These findings provide insights on nutrient composition of sesame seeds in Uganda, highlighting their potential health benefits and quality for culinary use and oil extraction.

CHAPTER ONE: INTRODUCTION

1.1 Background

Sesame (*Sesamum indicum*) has its origin in tropical Africa, from where it spread to the rest of the world and has been grown since the beginning of the systematic use of land to grow crops (Tunde-Akintunde, Oke, & Akintunde, 2012). Sesame plant is well adapted to dry conditions and grows best at elevations of 1000 to 2000 m above sea level in tropical and subtropical regions (Idowu *et al*., 2021). The leading producer of sesame in the world is Sudan, followed by Niger, Myanmar, India, the United Republic of Tanzania, Nigeria, Burkina Faso, Ethiopia, Uganda, Mozambique and Pakistan (FAOSTAT 2021). Sesame production has been on the increase worldwide and production increased from 5,516,868 to 6,549,725 metric tonnes in 2015 and 2019, respectively (FAOSTAT 2021). Increase in the production could be attributed to increase in sesame acreage from 10,083,017 ha in 2015 to 12,821,752 ha in 2019 (FAOSTAT 2021). Unlike the global trend, sesame seed production in Uganda stagnated at about 145,500 metric tonnes in the period 2015 to 2019 (FAOSTAT 2021). The biggest producers of sesame in Uganda are the Northern districts of Alebtong, Dokolo, Kole, Lira, Apac and Kaberamaido (Dalipagic, 2014).

Sesame of the genus *Sesamum* and family *Pedaliaceae* is among the top nine oil seed crops is one of the top nine oil seed crops, accounting for 90% of the edible oil produced worldwide.that make up 90% of the world's edible oil production (Bamigboye, Okafor, & Adepoju, 2010; Gharby *et al*., 2015). It is rich in edible oil, protein, carbohydrates implying that sesame is a good source of energy (Dissanayake, Ranwala, & Perera, 2017; Myint, Gilani, Kawase, & Watanabe, 2020). Sesame seed is also rich in minerals (phosphorous (P), iron (Fe), magnesium (Mg), calcium (Ca), manganese (Mn), copper (Cu) and zinc (Zn)), fibre and secondary metabolites such as phenolic compounds, tocopherol, phytosterols, saponins and lignans (Pathak, Kumari, & Bhat, 2014). Eighty percent of sesame oil is made up of UFA (Were *et al*., 2006; Dissanayake, Ranwala, & Perera, 2017). Due to its FA composition, the oil extracted from sesame is a common food ingredient, and is also used as a drug excipient by the pharmaceutical industry (Warra, 2011). Sesame protein has a higher concentration of essential amino acids, particularly methionine, cysteine, and tryptophan whose content is higher than that of other plant proteins such as soybean (Idowu *et al*., 2021). Due to sesame seeds' multi-functional properties such as water and oil-holding capacities, and foaming and emulsifying properties, sesame protein is used in making of various foods including sausage, bread and cakes. Raw sesame seeds contain anti-nutritional compounds such as protease trypsin inhibitors, which interfere with the digestibility of proteins (Embaby, 2010). According to Gowthami, Nayaka, & Gunashree (2021), raw sesames contains 0.45 mg/g of trysin inhibitors which are not harmful when consumed. Raw sesame seeds become more palatable and easier to digest when roasted or cooked, as heating reduces the trypsin inhibitors. Sesame contributes to the Sustainable Development Goal 2 on zero hunger in Uganda by providing a diverse and nutrient-rich food source that can supplement diets, particularly in regions with malnutrition (Namugumya, Candel, Talsma, & Termeer, 2020).

According to Xu *et al*., (2012), a landrace is a traditional or locally adapted variety of *Sesamum indicum* that has developed over time through natural selection and cultivation with many desired alleles for genetic improvement. Improved sesame seeds are ones that been developed through selective breeding or genetic modification to enhance traits like adaptability to specific environmental conditions, yield, flavor, disease resistance, oil content and other desirable characteristics. The sesame landraces grown include; *Adongo*, *Otara, Arut* and *Ajimo* and the improved sesame seeds include Sesim I, Sesim II and Sesim III (Walter, Karin, Agnes, & Stephan, 2017). Nowadays, studies on sesame around the world have concentrated on elucidating the chemical composition of the sesame seed (Unal & Yalcin, 2008; El Khier, Ishag, & Yagoub, 2008; Hassan, 2012; Ogbonna & Ukaan, 2013). The Commercial Agriculture for Smallholder and Agribusiness (CASA) report for sesame sector strategy in Uganda (2020) showed that improved sesame seeds yield better than the landrace sesame moreover the former is resistant to pests and diseases. Nonetheless, information on the composition of both landrace and improved sesame in Uganda is sparse (Mudingotto, Veena, & Mortensen, 2002). This study assessed the proximate, mineral and FA-composition, and quality of oil obtained from landrace and improved sesame seeds grown in Northern Uganda.

1.2 Statement of the problem

Sesame has tremendous export potential and ability to generate foreign exchange for Uganda and cash for the farmers. Sesame oil quality depends on the FA composition (Bakal, 2022), therefore there is need to know the FA composition of sesame seeds. There is limited information on the nutritional quality and health benefits of sesame seeds in Uganda. Improved sesame seeds are resistant to drought, pests or diseases and yield high amount of oil but the chemical composition of the seeds and oil is lacking. Lack of composition data makes the planning of the sesame value chain a challenge and hampers trade.

1.3 Objectives

1.3.1 General objective

To evaluate the proximate, mineral and fatty acid composition and quality of oil obtained from landrace (*Ajimo*, *Otara* and *Arut*) and improved (Sesim I, Sesim II and Sesim III) sesame seeds grown in Northern Uganda.

1.3.2 Specific objectives

The specific objectives of the study were to determine:

1. Proximate composition (moisture, total fat, crude protein, total ash, crude fibre, and carbohydrates) of landrace (*Ajimo*, *Otara* and *Arut*) and improved sesame seeds (Sesim I, Sesim II and Sesim III) in Northern Uganda;
2. The amount of minerals; P, K, Mg, Na, Ca, Fe and Zn of the landrace and improved sesame seeds;
3. The FA-composition of oil extracted from landrace and improved sesame seeds;
4. The quality parameters; refractive index (RI), acid value (AV), peroxide value (PV), and iodine value (IV) of oil extracted from landrace and improved sesame seeds.

1.4 Justification

Sesame is a non-traditional cash crop (Dijkstra, 2001) which plays a significant role in the global market and the demand for sesame and sesame products is on rise worldwide (FOASTAT, 2021). In Uganda, sesame is the second most essential oil seed crop after sunflower with more than 80% of the crop is grown in the Northern and Eastern regions of the country and plays a key role in diet and incomes of people (Wacal *et al*., 2021). The sesame seeds can undergo processing to create paste, oils, and are utilized in confectionary products like bread, snacks, cakes, and crackers. They are also used in animal feeds and as medicinal ingredients (Ssekabembe, 2007). The health potential of food depends on its qualitative and quantitative composition (Fardet, 2014). Sesame oil contains sesamol which is a special functional ingredient that protects against cancers, hypertension, hypercholesterolemia and for managing atherosclerosis, obesity, diabetes mellitus, chronic renal failure, rheumatoid arthritis, alzheimer's disease as well as dermatological diseases (Wacal *et al*., 2021). The proximate, mineral and FA compositions have been reported for sesame seeds in Egypt, Nigeria and Turkey (Akinoso, Igbeka, & Olayanju, 2006; Unal & Yalcin, 2008). Few studies have been done on sesame in Uganda and these were on mutation induction (Anyanga, 2001), value chain analysis and the quality of sesame seeds produced in Uganda (Munyua, Orr, & Okwadi, 2013). Were, Onkware, Gudu, Welander, & Carlsson (2006) also reported on FA composition of sesame oil in Uganda. However, there could be differences in nutrient composition over time due to the introduction of improved sesame varieties (Marles, 2017).

A lack of data on nutritional value of sesame seeds would hinder dietary choices and potentially lead to missed chances to improve local nutrition. Secondly, knowledge of benefits of landrace and improved sesame seeds would be restricted, hampering efforts to generate more nutritious and economically viable sesame. Finally, failure to conduct this study could have ramifications for food security, health, and economic well-being both locally in Uganda and other regions where sesame cultivation is significant. Therefore, this study assessed proximate and mineral composition, FA profile and quality parameters of oil extracted from selected landraces and improved sesame grown in Uganda.

1.5 Hypotheses

1. There is no difference in the proximate composition of landrace and improved sesame seeds grown in Northern Uganda.
2. There is no difference in the mineral content of landrace and improved sesame seeds grown in Northern Uganda.
3. There is no difference in the FA-composition of landrace and improved sesame seeds grown in Northern Uganda.
4. There is no difference in quality parameters of oil extracted from landrace and improved sesame seeds grown in Northern Uganda.

CHAPTER TWO: LITERATURE REVIEW

2.1 Taxonomy and cytogenetics of sesame

The *Sesamum* spp. (Family: *Pedaliaceae;* Genus*: Sesamum*) is spread distributed throughout the tropical and subtropical areas in Asia, Africa, and South America. Sesame is one of the oldest oil seed crops and a diploid (2n = 26) dicotyledon (Park *et al*., 2015). Thirty-six species of sesame of which 22 are found exclusively in Africa, 5 in Asia, one species each in Brazil, and the Crete of Greece, and 7 both in Africa and Asia, have been identified (Falusi *et al*., 2015). *Sesamum indicum* comprises hundreds of varieties and strains that differ considerably in plant size, form, growth pattern, color of flower, seed size, seed color and composition (Gadade, Kachare, Satbhai, & Naik, 2017). According to literature, *S.indicum* provides a valuable gene pool of local cultivars in USA, India, Russia, China, Kenya, South Korea and to a lesser extent Japan (Kafirit & Mponda, 2012). The South American collections resemble those from India and Ethiopia-Eritrea area, and similar types occur in East Africa (Kafirit & Mponda, 2012). The Indian region cultivars are comprehensively categorized into two types, i.e., early, few-flowered and little-branched, and late, multi-flowered and many-branched (Gulam, Sirato, & Masumi, 2007).

2.2 Sesame varieties

Sesame is a herbaceous plant that grows to between 0.6 m and 1.2 m high. S.*indicum* varieties are location and season specific (Nweke, Ubi, & Kunert, 2011). Some varieties of the plant are branched, while others are un-branched (FAO, 1998). The stem is square with grooves. Sesame leaves are have hairs on both sides and lanceolate, oval or oblong in shape. The upper leaves are undivided, irregularly serrate, and pointed, but the lower leaves are trilobed and occasionally trifoliate (Nagpurkar & Neeta, 2017). Sesame starts flowering from 35 - 45 days after planting and continues to fruit for 75 to 85 days for early varieties and lasts for 150 days for some varieties to mature. The flowers are zygomorphic with various shades of purple white color and a pendulous tubular corolla of 3 to 4 mm in length (De Andrade, Freitas, Rocha, de Lima, & Rufino, 2014). The shape of the sesame flower promotes cross-pollination, whose rate lies from 0.5 to 65% depending on environmental factors, insect activity and the presence of other flora (Mahmoud, 2012). Given conducive weather conditions, the sesame plant produces new leaves, blossoms and capsules at the same time. Sesame fruit is an oblong, sharp pointed 3 cm capsule covered with short soft hair that contains 50 to ≥ 100 seeds (Ashri, 2007). The maturity period of the seeds is 4 to 6 weeks after fertilization. Based on the color of seed coat, sesame is divided into black, white and yellow, but black and white are the most prevalent colors (Wang *et al*., 2018). A narrow genetic variation has been reported among sesame landraces assayed with morphological and molecular data in Uganda (Teklu, Shimelis, & Abady, 2022). In Uganda, *Adongo*, *Otara*, *Arut* and *Ajimo*, and Sesim I, Sesim II and Sesim III are the sesame landraces and improved varieties commonly grown (Table 2.1).

Table 2.1: Common sesame varieties grown in Uganda (UBOS, 2010)

Landrace	Plant height (cm)	Maturity period (days)	Seed color	Yield (kg/ha)
Adongo	100-150	>110	White	700
Otara	100-150	>100	White	600
Arut	100-150	>110	White	200-550
Ajimo	100-150	>110	White	500-700
Sesim I	100-120	110	White	900
Sesim II	100-150	110	White	1000-1800
Sesim III	100-120	100	White	1000-2000

2.4 Sesame cultivation and harvesting

Sesame thrives well in environments where few other crops can, due to its resilience to drought and high temperatures (Zhang, Miao, & Ming, 2013). Sesame grows best in well-drained sandy soils of pH 4.3 to 8.7 and rainfall of 500 to 650 mm per annum. The ideal temperature for sesame growth is between 25 and 35°C. Extreme low and high temperatures greatly affect sesame growth (Tafere, Wakjira, & Berhe, 2012). Proper timing for harvesting sesame prevents seed loss through shattering and ensures good quality of the harvested produce (Tafere, Wakjira, & Berhe, 2012). The current practice is to harvest sesame by hand, and leaving it to dry for the first 2 to 3 days (Azeez & Morakinyo, 2011). However, mechanical harvest is said to be better since it minimizes seed loss, and the hay left behind helps to preserve the fodder.

2.5 Status of sesame production

Due to interruptions in national economies, crop production and weather conditions, world sesame production is always fluctuating (Falusi *et al*., 2015). In 2019, the top ten world producing countries were Myanmar, India, Tanzania, Sudan, Ethiopia, Nigeria, Niger, Burkina Faso, Mozambique and Pakistan (FAOSTAT, 2021). In 2020, Sudan, China, Myanmar, the United Republic of Tanzania, India, Nigeria, Burkina Faso and Ethiopia were the leading producers (Teklu, Shimelis, & Abady, 2022). In 2019, Uganda was 9th and 7th biggest sesame seed producer in the world and Africa, respectively. Ethiopia, Burkina Faso, Nigeria, Tanzania, Niger, and Sudan were leading producers in Africa (FAOSTAT, 2021). Uganda's sesame acreage of 11.7 million hectares in 2018 was 1.8% of the world sesame acreage (Wacal *et al*., 2021). Average sesame seed yield in sub-Saharan Africa is less than 0.6 ton/ha. The low yield is caused by the use of unimproved landraces. The average sesame production of the world's top producing countries from 2016 to 2019 is given in Table 2.2.

Table 2.2: Production of sesame in the last seven years in tons

AREA	2016			2017			2018			2019		
	HA (ha)	Y (hg/h)	P (T)	HA (ha)	Y (hg/h)	P(T)	HA (ha)	Y (hg/h)	P (T)	HA (ha)	Y (hg/h)	P (T)
World	10,880,960	5,139	5,591,632	11,134,078	5,141	5,723,704	11,818,850	5,024	5,937,645	12,821,752	5,108	6,549,725
Africa	6,488,936	4,844	3,143,140	7,034,824	4,731	3,328,239	7,775,222	4,532	3,523,663	8,737,270	4,576	3,998,148
Asia	4,074,203	5,521	2,249,247	3,792,192	5796	2197787	3741357	5910	2211229	3661172	6139	2247431
East Africa	2,428,909	5,926	1,439,355	2320683	5860	1359863	2310559	5864	1354997	2411647	5990	1444647
America	316,985	6,253	198,220	306142	6,425	196,698	302,232	6,707	202,714	423,271	7,185	304,107
Europe	836	12,261	1,025	920	10,652	980	39	10,000	39	39	10,000	39
Sudan	2,134,860	2,459	525,000	2,704,000	2,888	781,000	3,480,960	2,758	960,000	4,243,680	2,851	1,210,000
India	1,900,000	3,932	747,000	1,666,930	4,481	747,030	1,579,770	4,782	755,430	1,419,970	4,854	689,310
Tanzania	1,010,000	7,228	730,000	850,000	7,294	620,000	900,000	7,111	640,000	940,000	7,234	680,000
Myanmar	1,495,250	5,437	812,952	1,478,181	5,171	764,323	1,491,788	4,796	715,437	150,563	4,946	744,498
Nigeria	928,467	6,393	593,604	1,012,730	6,244	632,317	693,134	6,925	4,800,000	586,539	8,184	480,000
Burkina Faso	282,442	5,804	163,920	291,173	5,625	163,787	438,941	5,785	253,936	617,749	6,066	374,703
Ethiopia	337,927	7,927	267,867	370,141	6,914	255,903	294,819	6,840	201,665	375,120	7,002	262,654
Uganda	207,000	6,522	135,000	208,000	7,019	146,000	213,000	6,761	144,000	212,000	6,792	144,000
Niger	129,912	5,136	66,722	117,321	4,199	49,263	190596	4,731	90,174	209,234	4,669	976,990
Mozambique	117,000	5,128	60,000	120,000	6,533	78,400	140,000	7,714	108,000	130,000	7,308	95,000
Pakistan	80,059	4,254	34,056	82,685	4,253	35,163	83,336	4,284	35,699	128,538	4,838	62,182

Source: FAOSTAT (2021)

2.6 Economic importance of sesame

2.6.1 Uses in the food industry

Sesame is cultivated largely for its oil with substantial sesame meal generated as a by-product that is used as a source of protein in food and animal feed, and as manure (Asghar, Majeed, & Akhtar, 2014). Whole or dehulled sesame seed is used as a flavoring or as a garnish for baked and confectionary products. Some bread, biscuits, and salad dressing have sesame seed as an ingredient or as a garnish. Sesame seed is also used in spreads, cookies, chickpea, doughnuts, breakfast cereals, broccoli rice, mustard sauce, rolls, crackers, cakes and pastry (Anilakumar, Pal, Khanum, & Bawa, 2010). Additionally, ground or whole sesame seed has been used as a wheat substitute in many baked goods.

2.6.2 Medicinal and pharmaceutical applications

Sesame is rich in ω-6 FA, vitamins, phenolic anti-oxidants and dietary fiber with health-promoting effects (Gadade, Kachare, Satbhai, & Naik, 2017). As a result, sesame is used for pharmaceutical purposes in medicine (Bedigian, 2004). Sesame fruits when fried in mustard oil are used for wound healing. The crushed sesame seed has been reported to be used in the treatment of abdominal pain. The seed extract is used in the treatment of haemorrhoids. Sesame seeds have also been used for the prevention and management of prostatic ailments (Mahabadi, Bafrani, & Nikzad, 2016). Sesame oil is an important pharmaceutical ingredient and is used in drug formulations (Nagpurkar & Neeta, 2017). Sesame oil is used to treat lung disease, inflammation, ulcers, vertigo, migraine, dry cough, asthma, and kidney disorders in addition to being an aphrodisiac and diuretic (Parle &

Nitin, 2006). The UFA found in the oil reduce hypercholesterolemia and hypertension, and prevent atherosclerosis, heart disease and cancer (Chandrakala, Krithika, Dmitry, & Sampath, 2015).

An antioxidant sesamolin, in, has been shown to hinder the development and induction of apoptosis in human lymphoid leukemia cells (Gbadamosi & Omobuwajo, 2017). In addition, sesamolin demonstrated anticancer activity on blood cancer Burkitt's lymphoma cells by improvement of Natural Killer (NK) cell lysis activity.

2.6.3 Other industrial uses of sesame

Sesame meal is used as an animal feed (Alege, Ojo, & Awosemo, 2013) and is also used as fertilizer (Deme, Haki, Retta, Woldegiorgis, & Geleta, 2017). Sesame oil is used in making soap, perfume, paint and insecticide. It is also useful in the perfumery and cosmetics industries where it is used to make skin care and hair products such as conditioners, moisturizers, bath oils, hand products and make-ups (Warra, 2011).

2.7 Nutritional composition of sesame seeds

2.7.1 Proximate composition

Proximate composition of foods is used for product development, quality control, and for regulatory purposes in the food industry. Sesame seed is rich in unsaturated oil, proteins, carbohydrates and fiber that are essential dietary elements. Sesame seed nutrition composition is dependent on genetics, landrace, ripening stage, harvesting time, and climate and environmental factors (Sangkhom & Onsaard, 2012).

2.7.1.1 Moisture

In general, sesame seed is low in moisture (Table 2.3), probably because the seed is small and flat (Teame, Tsegay, & Weldeareagy, 2021). According to Ogutcu, Arifoglu, Dincer, & Yilmaz (2017)the moisture content ranges between 3.2 and 4.7% while Gadade, Kachare, & Naik (2017), and Nzikou *et al*. (2010) reported the moisture content to be ≥ 5% and 10.2% on dry basis, respectively.

Table 2.3: Proximate composition (%) of sesame reported for selected studies in literature.

Parameter	1	2	3	4	5	6	7	8	9	10
Moisture	10.2	3.2-4.7	6.91	6.5	5.2	2.7	1.1	6.4	5.7	4.4
Protein	24.5	16.4-22.1	28.7	18.9	18.3	23.2	6.4	17.0	20.0	21.0
Fat	48.9	52.0-61.0	51.3	32.0	44.5	59.3	58.4	44.0	54.0	54.3
Fiber	3.2	6.0-20.0	4.6	1.8	3.7	7.3	7.6	4.6	3.2	-
Total ash	-	3.6-5.4	6.0	2.0	4.1	3.0	4.6	6.5	3.7	4.4
CH_2O	9.9	-	9.4	35.1	24.2	4.3	22.1	20.0	13.0	-

1. Gadade, Kachare, & Naik (2017); 2. Ogutcu, Arifoglu, Dincer, & Yilmaz (2017); 3. Okoronkwo, Osuji, & Nwankwo (2014); 4. Ogbonna & Ukaan (2013); 5. Bukya & Vijayakumar (2013); 6. Hassan (2012); 7. Nweke, Ubi, & Kunert (2011); 8. Bamigboye, Okafor, & Adepoju (2010); 9. Nzikou *et al*. (2010); 10. Unal & Yalcin (2008).

2.7.1.2 Protein

Sesame seed has been reported to contain protein ranging between 16.4% and 28.7% (Ogutcu, Arifoglu, Dincer, & Yilmaz, 2017). Dark sesame seed contains lower amounts of protein than white sesame seeds (Sangkhom & Onsaard, 2012). Sesame landraces contain higher amounts of protein than improved varieties (Anastasi *et al*., 2015). Sesame proteins (25.73%) contains adequate amounts of essential amino acids, sesame is used to enhance the nutrition of other foods especially vegetables (Fasuan, Gbadamos, & Omobuwajo, 2018).

2.7.1.3 Sesame seed oil and fat

Results from Adebowale, Sanni, & Falore, (2010) indicated the fat content of 44% for whole sesame seed and 48% for dehulled sesame seeds. According to Ogutcu, Arifoglu, Dincer, & Yilmaz (2017), the fat content of sesame seeds ranged from 52% to 61%. Sesame seed oil is comprised of 38% MUFA and 44% PUFA (Adebowale, Sanni, & Falore, 2010) Apart from its nutritional and pharmacological properties, sesame seed oil is characterized by a golden yellow color and a slightly nutty but neutral flavor (Betiku, Adepoju, Omole, & Aluko, 2012). The RI (40°C) of sesame oil ranges between 1.465 and 1.469, a typical range for edible oils (WHO/FAO, 2021). The relative density of oil ranges between 0.915 and 0.924 at 20°C, while the IV varies between 104 and 120 g/100 g (WHO/FAO, 2021). The high IV is due to the high amount of the UFA (Bhatnagar & Krishna, 2009).

2.7.1.4 Carbohydrate

Sesame is also a good source of carbohydrates (Borchani, Besbes, Blecker, & Attia, 2010). According to Nantel (1999), carbohydrates are the primary source of energy for humans, making up 40–80% of their overall caloric consumption. The content of carbohydrate is varies depending on the geographical source (El Harfi, Nabloussi, Rizki, Ennahli, & Hanine, 2019). Hassan (2012) reported a value of 4.3% for the carbohydrate content of sesame seed while Ogbonna & Ukaan (2013) reported the carbohydrate content to be 35.1%. According to Gadade, Kachare, Satbhai, & Naik (2017), sesame seeds have a carbohydrate composition that ranges from 7.3% to 12.2%.

2.7.1.5 Crude fiber

Like carbohydrates, the fiber content of sesame varies with geographical source (El Harfi, Nabloussi, Rizki, Ennahli, & Hanine, 2019). Alyemeni, Basahy, & Sher (2011) reported a crude fiber content of sesame seed of 2.9%. Adebowale, Sanni, & Falore (2010) reported the crude fiber content to be in the range of 3.4 to 5.6%. However, Ogutcu, Arifoglu, Dincer, & Yilmaz (2017) documented a crude fiber content between 6.0 and 20.0%. A food or food product is considered rich or high in fiber if it has ≥ 6 g of fiber per 100 g or ≥ 3 g of fiber per 100 kcal (Afifah *et al*., 2022). The fiber in sesame is important in the prevention of constipation, colorectal cancer, diabetes and obesity (Elleuch, Bedigian, Besbes, Blecker, & Attia, 2012).

2.7.1.6 Ash

The ash content of food is a vital component in a food's nutrition, quality and microbial viability. Different studies reported varying amounts of the ash content for sesame seed. According to Ogutcu, Arifoglu, Dincer, & Yilmaz (2017), the ash content of sesame seed ranges between 3.6 and 5.4% in Turkey. Alyemeni, Basahy, & Sher (2011) and Xu *et al*. (2012) reported an ash content of 6.9% and 5.7% in Saudi Arabia and China, respectively. However, Alege, Ojo, & Awosemo (2013) reported the ash content to range between 8.1 and 13.5%.

2.7.2 Fatty acid composition

Sesame oil belongs to oleic-linoleic acid group of vegetable oils with < 20% saturated FA (SFA) (Orsavova, Misurcova, Vavra Ambrozova, Vicha, & Mlcek, 2015). According to Gharby et al. (2015), linoleic acid (LA; 18:2ω6) and oleic acid (OA; 18:1ω9) make up more than 80% of total FA in sesame oil. The relative amounts of 18:1ω9 and 18:2ω6 in the oil are similar. The SFA portion comprises 7.9 to 12% and 4.8 to 6.1% of palmitic acid (PA,16:0) and stearic acid (18:0) respectively (Tyagi & Sharma, 2014). Besides the four major FA, there are small quantities of myristic (14:0), palmitoleic (16:1ω7), margaric or heptadecanoic (C17:0), alpha-(α)-linolenic (ALA; C18:3ω3), arachidic or icosanoic (C20:0), gondoic (C20:1 ω9), behenic or docosanoic (C22:0) and lignoceric or tetracosanoic (C24:0) acids (ElKhier, Ishag, & Yagoub, 2008). The FA-composition of sesame seed oils from selected studies in literature is shown in Table 2.4.

Table 2.4: Fatty acid composition (%) of sesame seed oil from selected studies in literature

Fatty acid	1	2	3	4	5	6	7	8	9	10
C16:0	9.11	16.3	8.27	9.57	9.52	11.49	5.6	7.49	10.5	8.24
C16:1	0.15	0.15	0.11	0.11	0.12	0.14	0.4	0.08	-	-
C18:0	5.15	10.4	5.69	4.99	6.02	2.64	5.3	4.04	4.9	4.89
C18:1	42.92	58.7	43.85	42.1	42.81	35.32	40.3	28.59	46.3	37.64
C18:2	39.7	47.2	0.36	42	39.07	47.62	46.1	28.35	36.1	47.82
C18:3	0.95	0.48	0.61	0.26	0.32	1.25	0.4	0.29	-	0.45
C20:0	0.69	0.99	-	0.63	-	0.52	0.5	0.35	1.1	0.5

C16:0: Palmitic acid; C16:1: Palmitoleic acid; C18:0: Stearic acid; C18:1: Oleic acid; C18:2: Linoleic acid; C18:3: linolenic acid; C20:0: Eicosanoic acid; 1. Ismail, El-Shewey, Shalaby, & Zaki (2019); 2. Adjepong, Jain, Pickens, Appaw, & Fenton (2018); 3. Matthaus & Özcan (2018); 4. Özdemir, Karaoglu, Dag, & Bekiroglu (2018); 5. Thakur, Paroha, & Mishra (2018); 6. Gouveia, Zago, & Moreira (2017); 7. Hama (2017); 8. Guimarães *et al*. (2013); 9. Hiremath, Patil, Patil, & Nagasampige (2007); 10. Were, Onkware, Gudu, Welander, & Carlsson (2006).

2.7.3 Mineral composition

Sesame seeds have high amounts of minerals including P, K, Mg, Ca, Fe, Mn, Cu and Zn that are crucial for functioning of the human body (Obiajunwa, Adebiyi, & Omode, 2005; Nzikou *et al*., 2010). Minerals are necessary for preserving normal nerve function, controlling muscular contractions to enable movement, and supporting a healthy cardiovascular system (Nzikou *et al.*, 2010). Minerals help in making strong bones, synthesis of red blood cells, synthesis of enzymes and hormones production (Soetan, Olaiya, & Oyewole, 2010). Differences in soil type where the plant grows, the genetic variation among varieties, and the sensitivity of analytical method used, are possible sources of the difference in mineral composition of sesame seeds from different geographical sources. Table 2.5 shows the mineral composition of sesame seed documented in the literature for different countries.

Table 2.5: Mineral composition (mg/100 g) of sesame seeds from selected studies in literature

Mineral	1	2	3	4	5	6	7
Ca	1463.5	1200	493.2	960	171.0	281.1	415.4
P	743.6	540	474.4	659	10.0	157.0	647.3
K	506.7	400	467.3	582	7.0	106.7	851. 4
Mg	364.8	370	396.5	362	81.0	-	579.0
Na	3.4	2	-	12	16.0	36.1	122.5
Fe	11.7	9.6	5.9	19.2	8.0	3.8	-
Zn	5.4	-	8.3	7.3	3.0	4.5	-
Cu	1.7	-	-	4.2	1.0	-	-

Ca: calcium; P: phosphorus; K: potassium; Mg: magnesium; Na: sodium; Fe: iron; Zn: zinc; Cu: copper; 1. Deme, Haki, Retta, Woldegiorgis, & Geleta (2017); 2. Singh, Kunwar, & Tripathi (2016); 4. Nagendra, *et al.* (2012);5. Adam, Colin, Matthieu, Alfonso, & Pablo (2015), 6. Bamigboye, Okafor, & Adepoju (2010); 7. Nzikou, et al. (2010)

2.8 Quality characteristic of sesame seed oil

2.8.1 Acid value

Acid value (AV) is an estimation of degree of free fatty acids (FFA) in one gram of vegetable oil. Acid value is an important specification for fat and oil quality that also reflects the pH of the fat or oil. The higher the AV, the lower the product pH (Kamrul, Bayazid, & Palash, 2019; Negash, Amare, Bitew, & Dagne, 2019). In addition, FFA levels increase with increasing (Kamrul, Bayazid, & Palash, 2019). The WHO/FAO set a maximum level of 4 mg KOH/g oil for AV of oils obtained without altering their nature by mechanical procedure (virgin oils) (CODEX-STANDARD-210., 1999).

2.8.2 Peroxide value

Peroxide value (PV) is the measurement of the concentration of peroxides in fats and oils, expressed in milliequivalents of active oxygen per kilogram of the sample and is therefore an indicator of oil's deterioration (Kamrul, Bayazid, & Palash, 2019). The PV is a function of storage temperature and time, and contact of the oils with air (Kamrul, Bayazid, & Palash, 2019). Low PV for oils is likely attributable to a high degree of saturation (Negash, Amare, Bitew, & Dagne, 2019). High PV values are an indication of low oil quality. The maximum level for the PV set by WHO/FAO for cold pressed and refined oils and virgin oils are 10 mEq O_2/kg oil and 15 mEq O_2/kg oil, respectively (CODEX-STANDARD-210., 1999).

2.8.3 Iodine value

Iodine value (IV) also known as iodine number measures the amount of double bonds in fatty acids within an oil, fat or lipid expressed in grams of iodine absorbed by 100 grams of the oil or fat. (Eze, 2012). The extent to which an oil is unsaturated reflects the susceptibility of the oil towards oxidation when exposed to air (Kamrul, Bayazid, & Palash, 2019). Oils rich in SFA have relatively low IV, which also ensures oxidative stability (Kamrul, Bayazid, & Palash, 2019).

2.8.4 Index of refraction

The index of refraction or refractive index (RI) is the ratio of light's velocity in a vacuum to its velocity in a given medium (Flores *et al*., 2021). The RI of a given substance changes with wavelength (λ) of the incident light and temperature at which measurement is done. Consequently, RI measurement is usually done using the Na D-light (λ=589.6 nm), and is reported at a reference temperature of 20°C. Measurements are also made at 40, 60, and 80°C for solid fats, hydrogenated fats and waxes, respectively (Flores *et al*., 2021). To adjust to the reference value at 20°C, equation 1 for estimating the RI at a different temperature has been suggested (Bradley, 2010).

$$n_D^{20} = n_D^{T} + (T-20) * 0.00045 \quad (1)$$

where; 0.00045 is correction factor of the RI per degree rise in temperature; n_D^{20} and n_D^{T} is the RI at T=20 and T°C, respectively.

Refractive index is an excellent measure of the uniformity of composition hence the purity and quality of fats and oils. It is an important attribute that can provide information on compositional changes. The RI varies with the FA chain length and degree of unsaturation. Therefore, RI determines the oil identity hence serving as an indicator of the quality of the oil (Gunstone, 2013; Ferreira-da-Silva *et al*., 2020). In comparison, triglycerides (TG) have higher RI than free fatty acids (FFA). Geometric isomers have different RI from one another, and the RI of conjugated polyenes differ from those of non-conjugated polyenes (Gunstone, 2013). Depending on the fat and oil variety, the RI of vegetable oils ranges between 1.44 and 1.47 (Endo, 2018). Table 2.6 shows the AV, PV, IV and RI for sesame seed oil from different studies in literature.

Table 2.6: The acid value, peroxide value, iodine value and refractive index of sesame seed oil obtained from literature compared with Codex Stan-210-1999

Characteristics	1	2	3	4	5	6
AV (mg KOH /g oil)	1.10	0.5	6.12	-	0.92	4
PV (mEq.O_2/kg oil)	0.19	8	6.59	0.1-0.5	8.99	15
IV (g I_2/100 g oil)	91.34	103	105.53	109.8-112.8	-	104 -120
RI (40˚C)	1.461	-	1.464	1.466	-	1.465-1.469

AV: acid value; PV: peroxide value; IV: iodine value/number; RI: refractive index; 1. Borchani, Blecker, Besbes, & Attia (2010); 2. Mohammed & Hamza (2008); 3. El Khier, Ishag, & Yagoub (2008); 4. Menezes, Budowski, & Dollear (1950); 5. Gouveia, Zago, & Moreira (2017); 6. CODEX-STANDARD-210 (1999)

CHAPTER THREE: MATERIALS AND METHODS

3.1 Materials

Landrace and improved sesame seeds were obtained from the Ministry of Agriculture Animal Industry and Fisheries (MAAIF), and the National Semi Arid Resources Research Institute (NaSARRI), Serere, respectively. Landraces included *Ajimo*, *Otara* and *Arut* and the improved verities included Sesim I, Sesim II and Sesim III. All chemicals used where of analytical grade. Petroleum ether (PE; boiling range 40 to 60°C) used to extract sesame oil was purchased from Labex Scientific. Pure standards of FA methyl esters (FAME) used to quantify the FA were also purchased from Labex Scientific.

3.2 Sampling and sample preparation

Three samples (1 kg each) of the improved sesame seeds (Sesim I, Sesim II and Sesim III) were obtained from NaSARRI. Further, three samples (1-3 kg) of each landrace sesame seeds were picked from farmers under MAAIF Vegetable Oil Development Project (VODP-Phase 2) making a total of 9 samples (Singharaj & Onsaard, 2012). The clean sesame seed was sealed in labelled sample bags and transported to Kyambogo University, Food Chemistry laboratory. All sesame seeds were conditioned in a hot air oven for 24 h at 50°C (Bamigboye, Okafor, & Adepoju, 2010) prior to analysis. The independent variables were landraces and improved sesame seeds and dependent were proximate, mineral, fatty composition and oil quality.

3.3 Methods

3.3.1 Determination of proximate composition

3.3.1.1. Moisture

The Association of Official Analytical Chemists (AOAC) Standard Method No. 44-15A was used to determine the moisture content (AOAC, 2000). Sesame seeds (5 g) was dried in a Memmert (model UN750, Germany) hot air oven at 105°C for 6 h. Moisture was calculated as the difference in weight of sample before and after drying.

3.3.1.2 Total fat

Total fat was determined according to AOAC Method No. 920.39 (AOAC, 2000). By this method, 5 g of sesame seeds was extracted using PE for 6 h. After completion of the extraction, the excess solvent was recovered on a rotovap and the crude lipid extract was transferred to the hot air oven set at 90^{o}C for 1 h for complete removal of the residual solvent.

3.3.1.3 Crude protein

Kjeldahl's method (Standard Method AOAC 979.09) was used to determine the total nitrogen (AOAC, 2000). Two grams of sesame seeds was transferred into a digestion flask and 0.5 g of $CuSO_4$ tablet was added followed by 15 ml of concentrated H_2SO_4. The homogeneous mixture was digested at 370^{o}C to a light green solution. The cool digest was diluted with distilled water (50 ml) and transferred into a 250 ml conical flask. Excess aqueous sodium hydroxide (NaOH; 40%) and 2 drops of methylene red and methyl blue mixed indicator were added. The mixture in flask was heated and ammonia liberated was collected in boric acid (H_3BO_3; 2%) contained in a collection flask. Total nitrogen (%) was determined by titrating the distillate with standardized 0.1N H_2SO_4. Protein content was estimated by multiplying the nitrogen content with a nitrogen-to-protein conversion factor of 5.30 (Mariotti, Tomé, & Mirand, 2008).

3.3.1.4 Crude fiber

Crude fibre was determined using a Dosi Fiber machine as described in Official Method AOAC 962.09. The defatted sample was weighed (0.4 g) out into the digestion column, 100 ml of 0.128 M of sulphuric acid; was added to the digestion column and mixture heated to boiling point on a hot plate at 130^{o}C. The mixture was cooled, filtered and the residue rinsed with hot deionized H_2O. 100 ml of 0.128 M potassium hydroxide was added and the mixture heated until a second boiling. The mixture was cooled, residue rinsed with warm deionized H_2O and was dried in the hot air oven at 140^{o}C for 45 min. It was then ashed at 550^{o}C for 1 h, cooled in a desiccator and the final weight recorded. Fiber content was calculated using equation 1.

$$\text{Fibre content (\%)} = \frac{\text{weight of the sample +crucible after dying} - \text{weight of sample+crucible after ashing}}{\text{weight of sample+weight of crucible} - \text{weight of the crucible}} \quad (1)$$

3.3.1.5 Total ash

Total ash was determined by the dry ashing method (AOAC Method No. 923.03). Two grams of sesame seeds was oven dried until constant weight. The dry sample was transferred to a muffle furnace (Carbolite-Gero 2132, United Kingdom) and incinerated to a white ash at 550°C. The ash content (%) was calculated using Equation 2:

$$\text{Ash (\%)} = \frac{\text{weight of white ash}}{\text{weight of original sample}} \times 100 \quad (2)$$

3.3.1.6 Total carbohydrates

The total carbohydrate content (%) was determined using by the difference method. Carbohydrate was calculated by subtracting the sum of moisture, protein, total lipid, ash, and fiber content from 100 (Ogungbenle & Onoge, 2014).

3.3.2 Fatty acid profiling

Fatty acids were profiled as FAME prepared following the procedure described in AOAC 996.06. The relative retention times of FAME peaks from the samples were compared with the FAME peaks of the pure standards. The FAME were prepared using 20% BF_3 in methanol and extracted with n-hexane. Fatty acid methyl ester analysis was done using a varian 3800 gas chromatograph manufactured by Varian Chromatography System (USA).

3.3.3 Determination of mineral elements

Sodium, K, Mg, Ca, P, Cu, Cu and Fe were determined in the sesame seeds using Flame Atomic Absorption Spectrophotometry; FAAS (AOAC 985.35). Analysis was done on a Hitachi Z6100 Atomic Absorption Spectrophotometer; AAS (Hitachi, Japan). Standard solutions of the respective metals were prepared at 5 different concentrations and absorbance (A) determined was in each case used to generate a calibration curve (Table 3.1). Two grams of sesame was ashed in Carbolite Gero 2132 muffle furnace (United Kingdom) at 550°C for 12 hours. The residual ash was dissolved in 20 ml of HNO_3 with 50 g/l of lanthanum chloride ($LaCl_3$). Samples were aspirated into AAS and absorbance measured is used to determine the concentration of the metal from the calibration curve of each metal. The metal concentration was recorded as the mean ± SD of 3 replicates.

Table 3.1: Wave length (λ) and standard calibration curves used in the AAS determinations

Element	λ (nm)	Concentration range (mg/L)	Equation of standard curve	R^2
Phosphorus	213.9	0.04-0.82	y= 0.0812x+0.0046	0.9998
Potassium	766.5	0.1002-0.6651	y= 0.08x+0.0311	0.9987
Magnesium	285.2	0.1615-1826	y= 1.0814x+0.0486	0.9996
Sodium	589	0.1246-1.0789	y= 0.1368x-0.0038	0.9989
Calcium	422.7	0.2186-0.8789	y= 0.0326+0.0652	0.9989
Iron	248.3	0.0348-08491	y=0.0847x+0.0035	0.9995
Zinc	213.9	0.0303-0.2777	y= 0.1292x+0.0204	0.9994
Copper	324.7	0.01-0.2306	y= 0.1154x+0.0012	0.9994

3.3.4 Determination of sesame seed oil quality

The RI, content of FFA expressed as the AV, PV and IV are physico-chemical parameters commonly used to assess the quality of edible oils (Gharby *et al*., 2015).

3.3.4.1 Refractive index

The RI was determined on an Abbemat 3200 refractometer (Anton Paar, Germany) at 20°C after zeroing out the instrument with deionised water (AOAC method 921.08).

3.3.4.2 Acid value

The protocol of the American Oil Chemists Society; AOCS (Standard Method AOCS 5a-40) was used to determine the AV. Sesame was weighed (0.3 g) out into an Erlenmeyer flask and 125 ml of n-Hexane added. The flask and its contents was shaken in a circular motion to allow complete dissolution of the test portion before titration. Using phenolphthalein indicator, the mixture was titrated against 0.02 M KOH solution. A blank (without oil sample) was similarly determined. The AV was calculated using equation 3.

$$\text{Acid value} = \frac{\{56.11)\text{xN } (V_S - V_b\}}{W} \quad (3)$$

where;

V_S= volume of 0.02 N KOH required to titrate given weight (W) of sesame oil, V_b= titration volume of blank (ml), W=weight of sesame oil used, M=0.02= Molarity of KOH solution, 56.11 = molecular weight of KOH.

3.3.4.3 Peroxide value

Peroxide value was determined following the procedure described in standard method AOCS Cd 8b-90 (Yu, Li, Sun, Dong, & Wang, 2015). Sesame oil (0.3 g) was weighed out into a 250 ml conical flask. A 50 ml of 3:2 acetic acid–isooctane mixture was added and the flask and its contents swirled to completely dissolve the sample. Saturated KI solution (0.5 ml) was added followed by vigorous shaking. The mixture was allowed to stand for one minute, followed by addition of 30 ml of distilled water, and mixture titrated with 0.1N $Na_2S_2O_3$ until the brown color of iodine turned pale yellow. Ten percent of sodium dodecyl sulfate (SDS; CH3(CH2)11OSO3Na) (0.5 ml) was added followed by 0.5 ml of starch indicator and titrated until the blue color was discharged. A blank was similarly determined. The PV was calculated using equation 4.

$$PV=\frac{(VS-VB) \text{ x } F \text{ x}10)}{W} \quad (4)$$

where; VS= titration volume of sesame oil, VB= titration volume of blank, F= factor of 0.01 N $Na_2S_2O_3$, W= weight of sesame oil used, N=Normality of $Na_2S_2O_3$, 10 is a conversion factor of mole to milliequivalent.

3.3.4.4 Iodine value

Iodine value was determined in accordance with Standard Method AOAC 993.20 (AOAC, 1990). Sesame oil (0.25 g) was dissolved in 10 ml of dichloromethane in a 500 ml iodine flask. Aqueous IBr (25 ml) was added and the flask and its contents kept into the dark for 30 minutes. The flask was exposed to light and 20 ml of aqueous KI was added while swirling in order to homogenize the mixture. Distilled water (150 ml) was subsequently added and the mixture titrated to a pale-yellow color with 0.1 N $Na_2S_2O_3$. Starch indicator (2 drops) were added and the mixture titrated until the blue color of starch was discharged. A blank (without the oil) was similarly determined. The IV was calculated using Equation 5.

$$\text{Iodine value } = \frac{(VB-VS)\times N\times 12.69}{W} \quad (5)$$

where VB = mL $Na_2S_2O_3$ used for blank determination, VS = mL $Na_2S_2O_3$ used for sesame oil determination, N=Normality of $Na_2S_2O_3$, W = weight of sesame oil used (g).

3.5 Statistical analysis

All analyses were done in triplicate and the results recorded as the mean±SD. The data obtained was analyzed for ANOVA using IBM SPSS software version 22. The significant difference among means was obtained using Duncan's test. Mean differences were considered significant at $p < 0.05$.

CHAPTER FOUR: RESEARCH FINDINGS AND DISCUSSIONS

4.1 Proximate composition of landrace and improved sesame seeds

Sesame seeds contained 4.86 to 5.94% moisture, 30.59 to 42.54% crude oil, 19.59 to 22.32% crude protein, 5.72 to 7.64% crude fiber, 4.55 to 5.15% total ash, and 21.95 to 33.30% carbohydrate (Table 4.1).

Table 4.1: Proximate composition (% w/w) of landrace and improved sesame seeds

Varieties	Moisture	Total fat	C. Protein	Total ash	Crude fibre	Carbohydrate
Sesim I	5.94 ± 0.02^{a}	38.95 ± 0.24^{b}	19.82 ± 0.12^{c}	4.55 ± 0.09^{c}	7.08 ± 0.01^{b}	23.67 ± 0.06^{c}
Sesim II	4.86 ± 0.07^{e}	39.34 ± 0.13^{b}	21.17 ± 0.28^{b}	5.02 ± 0.16^{a}	7.64 ± 0.66^{a}	21.95 ± 0.95^{c}
Sesim III	5.25 ± 0.11^{c}	39.05 ± 0.28^{b}	22.32 ± 0.58^{a}	5.15 ± 0.07^{a}	7.13 ± 1.49^{b}	26.40 ± 0.90^{b}
Arut	5.58 ± 0.01^{b}	34.90 ± 3.89^{d}	19.61 ± 0.83^{d}	4.87 ± 0.25^{b}	6.10 ± 0.62^{c}	28.59 ± 3.90^{b}
Otara	5.04 ± 0.06^{d}	42.54 ± 4.38^{a}	19.59 ± 0.24^{d}	4.69 ± 0.06^{bc}	$5.72. \pm 0.63^{d}$	22.51 ± 4.22^{c}
Ajimo	5.48 ± 0.14^{b}	30.59 ± 10.56^{d}	19.99 ± 0.25^{c}	4.90 ± 0.43^{b}	5.76 ± 0.42^{d}	33.30 ± 10.35^{a}

C. protein: crude protein; averages are the mean ± standard deviation of 3 replicates; values with different superscript in the same column are significantly ($p<0.05$) different.

The moisture content of different sesame seeds showed variability. Amongst the landraces, *Otara* had a significantly ($p<0.05$) lower moisture content than *Arut* and *Ajimo*. For the improved sesame seeds, Sesim I had the highest moisture content while Sesim II had the lowest. Adebowale, Sanni, & Falore (2010), Ebere, Chukwuemeka, & Chinedu (2019) and El-Harfi, Nabloussi, Rizki, Ennahli, & Hanine (2019) reported a moisture range between 1 and 10% for brown and white sesame seeds. Sesame seeds must be stored at a moisture content ≤ 6% because it is difficult to aerate such small seeds in a storage bin. Low moisture is an indicator of stability, quality and shelf life (Negash, Amare, Bitew, & Dagne, 2019). If kept too moist, sesame seeds quickly heat up and develop a rancid oil taste (Ling, Zaman, Rosidi, Hassan, & Yang, 2018).

The landrace (*Otara*) yielded higher ($p<0.05$) amount (42.54%) of oil when compared to other landraces (Table 4.1). There was no difference ($p>0.05$) in oil yield among improved sesame seeds. Similarly, there was no significant difference between the oil yield of *Arut* and *Ajimo* landraces. According to Pusadkar, Kokiladevi, Bonde, & Mohite (2015), sesame contains 34.4 to 59.8% of the seed weight as oil. Findings of this study imply that *Ajimo* landrace yielded lowest amount (30.59%) of oil than previously reported by Gadade, Kachare, Satbhai, & Naik (2017).

Protein content showed variability among the different landraces. In general, the protein content of the improved sesame seeds was higher than that of the landraces. The highest amount (22.32%) of protein was observed in the Sesim III and the lowest was observed in the landrace *Arut* (Table 4.1). These results are in line with those reported by Ogutcu, Arifoglu, Dincer, & Yilmaz, 2017. WHO recommends consuming 2.96 g of sesame seeds daily in one serving.

Sesim III registered the highest amount (5.15%) of total ash while Sesim I showed the lowest (4.55%). Sesame landraces had lower ash content than the improved sesame seeds therefore, the latter would provide more minerals in the diet. Results of this study agree with those of Unal & Yalcin (2008) who reported total ash content ranging from 3.67 to 5.39% for Turkish, Mexican, Uganda and Venezuela sesame varieties.

Improved sesame seeds had higher fiber content than the landraces. Sesim II had the highest amount of fiber content of 7.64% whereas *Otara* had the lowest (5.72%). There was no significant difference ($p>0.05$) in the fibre content of Sesim I and Sesim III improved sesame seeds. Similarly, the fiber content of *Arut* and *Ajimo* landraces did not differ. Crude fibre content of landraces was higher than the amount of 5.61% reported for white sesame seeds by Ali, Mahmoud, Aldoma, & Hamadnalla (2020).

Carbohydrate constituted the second largest portion in the sesame seeds. A higher carbohydrate content was observed in landraces than in improved sesame seeds. The highest amount (33.30%) of carbohydrate was registered by *Ajimo* landrace and the lowest (21.95%) by Sesim II improved sesame seed. There was no significant difference ($p>0.05$) in the carbohydrate content of Sesim I, Sesim II and *Otara*. Similarly, there was no significant difference between Sesim III and *Arut* sesame seeds. Nweke, Ubi, & Kunert (2011) and Ogbonna & Ukaan (2013) reported the carbohydrate content in sesame seeds to be 15.68 to 28.05% and 35.1%, respectively. The composition of sesame seeds vary due to multiple factors, including varietal differences, growing conditions, harvesting time, processing methods, storage conditions, genetic variation, geographical origin, cultivation practices, and post-harvest handling (Gharby *et al*., 2015). Different sesame seeds exhibit variations in protein, fat, and carbohydrate content, influenced by their genetic traits and environmental conditions. The timing of seed harvest, along with the processing and storage methods, can also affect moisture content and oil composition.

4.2 Fatty acid composition of landrace and improved sesame seeds

Table 4.2 shows a total of 12 FA that were identified in the sesame seeds. Of the 12 FA, myristic acid (14:0), hexadecanoic acid (C16:0), heptadecanoic acid (C17:0), eicosanoic acid (18:0), docosanoic (C20:0) and heneicosanoic acid (C21:0) were SFA while palmitoleic acid (16:1ω7), oleic acid (18:1ω9), linoleic acid (18:2ω6), linolenic acid (18:3ω3) and gondoic acid (C20:1ω9) were UFA. Fatty acid C16:0, C16:1ω7, C18:0, C18:1ω9, C18:2ω6, C20:0, C20:1ω9 and C21:0

was detected in all sesame seeds. Myristic acid and C18:3ω3 was detected in Sesim I and Sesim II only. Margaric acid was detected in Sesim I, Sesim II and *Otara*. Behenic acid was detected in all samples except *Ajimo*.

Table 4.2 Fatty acid profile of landrace and improved sesame seeds grown in Uganda

Fatty acid	Sesim I	Sesim II	Sesim III	*Arut*	*Otara*	*Ajimo*
C14:0	$0.18±0.01^{a}$	$0.14±0.01^{b}$	ND	ND	ND	ND
C16:0	$9.11±0.01^{b}$	$8.69±0.01^{c}$	$10.63±0.06^{a}$	$9.07±0.73^{b}$	$8.74±0.25^{c}$	$8.81±0.42^{c}$
C16:1ω7	$0.44±0.01^{a}$	$0.33±0.001^{b}$	$0.19±0.01^{c}$	$0.33±0.33^{b}$	$0.13±0.01^{d}$	$0.15±0.03^{d}$
C17:0	$0.11±0.00^{b}$	$0.12±0.00^{a}$	ND	ND	$0.06±0.01^{c}$	ND
C18:0	$6.82±0.02^{b}$	$6.59±0.01^{c}$	$8.12±0.01^{a}$	$5.82±0.44^{d}$	$6.31±0.75^{c}$	$6.07±0.15^{c}$
C18:1ω9	$41.35±0.01^{c}$	$41.71±0.01^{b}$	$46.70±0.02^{a}$	$38.90±1.24^{e}$	$39.05±3.03^{d}$	$38.79±0.09^{e}$
C18:2ω6	$37.98±0.01^{c}$	$40.16±0.01^{b}$	$30.57±0.02^{d}$	$42.92±2.02^{a}$	$42.38±4.64^{a}$	$42.05±0.46^{a}$
C18:3ω3	$0.08±0.01^{a}$	$0.05±0.01^{b}$	ND	ND	ND	ND
C20:0	$0.83±0.01^{ab}$	$0.83±0.01^{ab}$	$1.04±0.01^{a}$	$0.78±0.06^{b}$	$0.78±0.01^{b}$	$0.83±0.01^{ab}$
C20:1ω9	$0.27±0.01^{a}$	$0.23±0.02^{b}$	$0.23±0.04^{b}$	$0.16±0.03^{d}$	$0.20±0.03^{c}$	$0.18±0.00^{c}$
C21:0	$0.34±0.01^{ab}$	$0.36±0.01^{a}$	$0.15±0.01^{c}$	$0.37±0.01^{a}$	$0.31±0.02^{a}$	$0.36±0.01^{a}$
C22:0	$0.30±0.01^{a}$	$0.22±0.01^{c}$	$0.27±0.01^{b}$	$0.16±0.02^{d}$	$0.18±0.01^{d}$	ND
SFA	17.69	16.95	20.21	16.2	16.38	16.07
MUFA	42.06	42.27	47.12	39.39	39.38	39.12
PUFA	38.06	40.21	30.57	42.92	42.38	42.05
P/S	2.15	2.37	1.51	2.65	2.59	2.62
ω6/ω3	474.5	803.2	-	-	-	-

Values are the mean ± standard deviation of 3 replicates; values with different superscripts in a row are significantly ($p<0.05$) different; C14:0-myristric acid; C16:0-palmitic acid; C16:1ω7-Cis-palmitoleic acid; C17:0-heptadecanoic acid; C18:0-stearic acid; C18:1ω9-oleic acid; C18:2ω6-Cis-linoleic acid; C18:3ω3-alpha linolenic acid; C20:0-eicosanoic acid; C20:1ω9-gondoic acid; C21:0-heneicosanoic acid; C22:0-behenic acid; SFA; saturated fatty acids; MUFA; monounsaturated fatty acids; PUFA; polyunsaturated fatty acids; P/S=PUFA/SFA; ω6= C18:2ω6; ω3= C18:3ω3, ND – Not Detected.

The major FA were C16:0, C18:0, C18:1ω9 and C18:2ω6. The four FA together contributed > 95% of the total FA (Table 4.2). Unsaturated FA predominated over the SFA. All the other FA were present in small amounts i.e., less than one percent. Linoleic acid and C18:1ω9 ranged from 30.57 to 42.92% and 38.90 to 46.70%, respectively. The composition of these FA was variable among the different samples. Landraces had higher amounts (42.92, 42.38 and 42.05%) of C18:2ω6 than the improved sesame seeds (Table 4.2). On the other hand, improved sesame seeds were high in C18:1ω9. *Otara* landrace registered the highest amount (42.92%) of C18:2ω6 while Sesim III improved sesame seed registered the lowest. Sesim III showed the highest amount of C18:1ω9 and *Otara* the lowest. The FA composition of sesame seed oils from different countries vary because of variation in climatic conditions, soil type, cultivars and plant maturity (El Khier, Ishag, & Yagoub, 2008; Gharbia, KeÂfi, & Yahia, 2017).

Palmitic acid and C18:0 were predominant SFA and ranged from 8.69 to 10.63% and 5.82 to 8.12%, respectively. Overall, improved sesame varieties contained higher amounts (9.11, 8.69 and 10.63% of C16:0 than the landraces (Table 4.2). The highest and lowest amount (8.69 and 10.63%) of C16:0 was correspondingly observed in Sesim III and Sesim II. Stearic acid was highest in Sesim III and lowest in Arut. The amount of C16:0 and C18:0 analyzed in this study was lower than those reported by Yol, Toker, Golukcu, & Uzun (2015).

More than 80% of the total FA composition of sesame comprises C18:1ω9 and C18:2ω6 (Uzun, Arslan, & Furat, 2008; El-Harfi, Nabloussi, Rizki, Ennahli, & Hanine, 2019; Agidew, Dubale, Atlabachew, & Abebe, 2021). Palmitic, C18:0, C18:1ω9, and C18:2ω6 acids have been reported as the principal FA in cultivated sesame (Nimmakayala, Perumal, Mulpuri, & Reddy, 2011). From a nutritional point of view, C18:2ω6 and C18:3ω3 are essential FA (EFA), which are obtained from the diet. Essential FA intake is positively correlated with the reduction of cardiovascular, neurological, visual, and cancer disorders (Montesano *et al*., 2018). FA composition of sesame seeds findings of this study show low levels of C18:3ω3, similar to the Thakur, Paroha, & Mishra (2018) and Guimarães, et al. (2013) with 0.32% and 0.29 %, respectively.

Saturated fatty acids, MUFA and PUFA in improved and landraces sesame seeds ranged between 16.07 and 20.21%, 39.12 and 47.12%, and 30.57 and 42.92%, respectively. The amount of SFA in this study was close to those previously reported by Gharby, *et al*. (2015). Landrace seeds had more PUFA than the improved seeds. The landrace *Arut* registered the highest value while Sesim III registered the lowest. The observed proportion of PUFA was similar to those reported by Diana, *et al*. (2021). The P/S ratio ranged between 1.5 and 2.65 for landrace and improved sesame seeds. The results show lower ratios in the improved than in the landrace seeds. Foods with a PUFA/SFA ratio > 0.45 have been considered desirable in the diet because of greater hypocholesterolemic effects than those with lower ratios (Chang & Huang, 1998). The PUFA/SFA ratio observed in this study would favor the reduction of the possibility of CVD (Kang *et al*., 2005). The ratio of ω6/ω3 were 474.5 and 803.2 in Sesim I and Sesim II which were higher than 130.09 obtained Diana et al. (2021). The ratio of ω6/ω3 is a key index for nutritional significance of lipids whereby diets with a ω6/ω3 ratio of up to 4.0 is attributed to a 70% decrease in death from CVD (Gualda *et al*., 2018). A high ω6 proportion (ω6/ω3 > 10) largely made up by 18:2ω6 as observed in this study is far from optimal (Simopoulos, 2016). Therefore, sesame seed would have to be blended with other seeds rich in 18:3ω3 so as to improve on the nutrition quality.

4. 3 The mineral composition of landrace and improved sesame seeds

Mineral concentrations were significantly different in both the improved and landrace sesame seeds and ranged from 521.45 to 665.15, 315.70 to 458.22, 199.60 to 363.16, 69.29 to 83.15, 50.42

to 56.40, 2.32 to 2.86, 1.12 to 2.86 and 1.13 to 1.59 mg/100 g for P, K, Mg, Na, Ca, Fe, Zn and Cu, respectively (Table 4.3).

The highest and lowest concentration of P was registered in *Otara* and *Ajimo* landraces, respectively. Phosphorous was found to be variable in landrace sesame seeds. On the other hand, there was no observable difference in the concentration of P in the seeds of the improved varieties. Phosphorous content was similar to that reported by Eyasu, Dawit, Ashebir, & Gobeze (2021). A corresponding serving of improved and landrace sesame (100 g) would meet 93.1% and 87.9% of the RDA for P for both adult male and female. According to Article 7 of Regulation (EC) No. 1925/2006 of the European Parliament and of the Council of 20 December 2006, a claim that a food is high in a certain mineral and any claim likely to have the same meaning for the consumer, is authorized only if the product contains at least twice the value of "source of name of vitamins and minerals". As a rule, 15 % of the nutrient reference values specified in point 1 supplied by 100 g or 100 ml in the case of products other than beverages should be taken into consideration in determining what constitutes a significant amount. The findings of this study indicate that landrace and improved sesame seeds are high in phosphorus.

Table 4.3: Mineral composition (mg/100 g) of landrace and improved sesame seeds grown in Uganda

Element	Improved			Landrace			Mean (mg)	
	Sesim I	Sesim II	Sesim III	*Arut*	*Otara*	*Ajimo*	Improved	landrace
P	649.71±0.71[ab]	659.46±0.29[b]	646.23±1.99[ab]	658.94±9.07[b]	665.15±5.26[a]	521.45±1.45[c]	651.8	615.18
K	315.70±0.38[f]	403.10±0.13[c]	415.46±2.04[b]	386.11±2.43[d]	364.95±29.13[e]	458.22±10.90[a]	378.09	403.09
Mg	199.60±0.76[f]	260.17±2.05[d]	294.70±3.95[b]	255.79±0.25[e]	272.88±5.93[c]	363.16±0.52[a]	251.49	297.28
Na	69.29±0.10[e]	79.00±1.22[b]	78.32±1.45[b]	75.30±1.32[c]	72.91±0.97[d]	83.15±1.28[a]	75.54	77.12
Ca	55.10±1.58[b]	50.42±0.08[c]	55.50±0.33[b]	51.03±6.74[c]	50.46±3.59[c]	56.40±11.87[a]	53.67	52.63
Fe	2.32±0.03[d]	2.86±0.04[a]	2.33±0.03[d]	2.77±0.12[b]	2.74±0.01[b]	2.56±0.05[c]	2.5	2.69
Zn	1.12±0.18[f]	1.79±0.09[e]	1.94±0.02[d]	2.41±0.37[c]	2.56±0.02[b]	2.77±0.03[a]	1.62	2.58
Cu	1.34±0.08[a]	1.33±0.03[a]	1.35± 0.10[a]	1.32± 0.02[a]	1.13±0.12[a]	1.59± 0.05[a]	1.34	1.35
Na/K	0.22	0.2	0.19	0.2	0.2	0.18	0.2	0.19

P: phosphorus; K: potassium; Mg; magnesium; Na: sodium; Ca; calcium; Fe: iron; Zn: zinc; Cu: copper; Values are means ± standard deviation of three replicates; for Mg, Ca, Fe and Zn, values in row with different superscripts are significantly different ($p<0.05$); [1]Ross, Taylor, Yaktine, & Del Valle (2011).

The concentration of K varied among sesame seeds. The highest concentration was recorded for *Ajimo* and lowest for the Sesim I. Potassium concentration in sesame seeds was lower than reported in previous studies (Bamigboye, Okafor, & Adepoju, 2010). Potassium is required for the function of all living cells, and is thus present in all animal and plant tissues. It is the major abundant cation in intracellular fluid because it is crucial in maintaining the normal cell functions (Udensi & Tchounwou, 2017).

Like K, Mg concentration also varied among sesame seeds. *Ajimo* landrace had the highest concentration while Sesim I had the lowest. Magnesium concentration was in line with that of Deme, Haki, Retta, Woldegiorgis, & Geleta (2017) who reported Mg in sesame seeds to range from 264 to 352 mg/100 g. Sesim I was however below the range. The deficiency of Mg and habitual low intakes of this element may lead to an upsurge in the risk of developing chronic diseases (Fiorentini, Cappadone, Farruggia, & Prata, 2021). According to literature, people who consume Western-type diets as is now common in Uganda, are low in Mg, i.e. < 30% to 50% of the RDA of Mg (Gröber, Schmidt, & Kisters, 2015; Castiglioni, 2021). According to Bohn, (2008) foods containing dietary fiber are a good source of Mg hence the inclusion of sesame seed in the diet will contribute towards meeting the RDA.

Ajimo landrace had the highest concentration of Na while the lowest was observed in Sesim I. There was no significant difference ($p > 0.05$) in the concentration of Na between Sesim II and Sesim III improved sesame seeds while significant ($p < 0.05$) difference was observed among landraces. Sodium concentration was comparable with that reported by Alyemeni, Basahy, & Sheri (2011). Sodium is necessary for health and serves many physiological functions, including nutrient absorption, and maintenance of fluid balance and blood pressure (Cook, Feng, MacGregor, &

Graudal, 2020; Farquhar, Edwards, Jurkovitz, & Weintraub, 2015). Nonetheless, a high Na/K ratio is a strong indicator of increased risk of disease than the level of either Na or K alone (Baer *et al*., 2022). The best balance of Na and K intakes for preventing cardiovascular diseases and reducing the death rate from all causes of death for a population in a particular time, has been recognized to be at a Na/K ratio of < 1.0 (Mirmiran *et al*., 2021). The Na and K findings of this study suggest that landrace and improved sesame seeds had a Na/K ratio < 1.0. This means that sesame can be included in the diet of the general population for the purpose of preventing CVD (Sarah, Majdalawieh, & Manjikian, 2020). However, sesame may not be considered a dietary source of Na due its small portion it contributes to the RDA.

In as far as Ca is concerned, *Ajimo* landrace presented the highest concentration while Sesim II the lowest. Calcium concentration did not present significant difference (P>0.050) between *Arut* and *Otara* landraces. Similarly, there was no significant difference between Sesim I and Sesim III improved sesame seeds. Calcium concentration was less than that previously reported (Zebib, Bultosa, & Abera, 2015; Olagunju & Ifesan, 2018). Like for Na, sesame is not a source of Ca.

The highest Fe concentration was registered in Sesim II and the lowest in Sesim I. Generally, there was variation in the Fe concentration between improved and sesame landraces. There was no significant difference in Fe concentration between *Arut* and *Otara* landraces. Iron concentration was lower than reported in previous studies (Haftom, Geremew, & Solomon, 2015; Zebib, Bultosa, & Abera, 2015; Deme, Haki, Retta, Woldegiorgis, & Geleta 2017). There is no significant difference between landrace and improved sesame seeds. The human body requires sufficient amounts of Fe for the synthesis of myoglobin and hemoglobin, and for the formation of heme- and other Fe-containing enzymes involved in oxidation-reductions and electron transfer (Abbaspour, Hurrell, & Kelishadi, 2014). When one does not have enough Fe in the body, they develop a nutritional deficiency known as Fe-deficiency anemia (IDA). The most common deficiency affecting *ca.* 30% of the world's population is IDA (Kumar, Sharma, Marley, Samaan, & Brookes, 2022).

The highest concentration of Zn was observed in *Ajimo* while the lowest was in Sesim I. Zinc concentration showed variability among the different sesame seed types. Landraces had higher concentration of Zn than that of the improved sesame seeds. Zinc concentration was lower than that reported by Deme, Haki, Retta, Woldegiorgis, & Geleta (2017). Zinc is needed for DNA synthesis, RNA transcription, cell proliferation, growth and immune system function, and is a cofactor of many metalloenzymes (Abdel *et al*., 2021). Zinc deficiency is a risk factor for immune deficiency and susceptibility to infection especially in children and the elderly. Populations in South East Asia, South Asia and sub-Saharan Africa are at high risk of zinc deficiency.

Copper was highest and lowest in *Ajimo* and *Otara* landraces, respectively. The concentration of Cu did not present significant ($p > 0.05$) difference among different sesame types. Copper is a trace element that is important for cardiovascular integrity, growth, neovascularization, lung elasticity, Fe metabolism and neuroendocrine function (Patel & Aschner, 2021). Because too little and too much Cu is associated with organ dysfunction, oxidative cell damage and compromised immune function, the absorption, uptake and transport of Cu in the human body are highly regulated (Barber, Grenier, & Burkhead, 2021). The Tolerable Upper Intake Level (UL) for copper for adults 19+ years and pregnant and lactating women is 10 mg/day.

4.4 Quality parameters of oil extracted from landrace and improved sesame

Oils from all the landrace and improved sesame seeds registered a RI of 1.466 as given in Table 4.4. The RI observed for the sesame seed oil was similar to that previously reported in literature (ElKhier, Ishag, & Yagoub, 2008). The RI of sesame oil ranged from 1.465 to 1.469 when measured at 40°C, meaning that the extracted sesame oils were within the range specified in CODEX-STAN 210. The RI relies on the FA and triglyceride (TG) composition of an oil and it therefore measures the oil's purity (Gharby *et al*., 2015).

Table 4.4: Refractive index, acid value, peroxide value and iodine value of oil extracted from the landrace and improved sesame seeds

Parameter	Sesim I	Sesim II	Sesim III	*Arut*	*Otara*	*Ajimo*
RI	$1.466{\pm}0.00^{a}$	$1.466{\pm}0.00^{a}$	$1.466{\pm}0.00^{a}$	$1.466{\pm}0.00^{a}$	$1.466{\pm}0.00^{a}$	$1.466{\pm}0.00^{a}$
AV	$2.30{\pm}0.10^{c}$	$2.30{\pm}0.20^{c}$	$4.07{\pm}0.12^{a}$	$3.19{\pm}1.00^{b}$	$2.52{\pm}0.59^{c}$	$2.90{\pm}0.87^{bc}$
PV	$6.00{\pm}2.00^{a}$	$6.00{\pm}1.00^{a}$	$4.00{\pm}1.00^{c}$	$5.55{\pm}0.39^{a}$	$5.56{\pm}0.20^{a}$	$4.89{\pm}0.84^{b}$
IV	$93.09{\pm}0.11^{a}$	$93.66{\pm}0.05^{a}$	$85.09{\pm}0.31^{b}$	$94.57{\pm}1.45^{a}$	$89.88{\pm}3.44^{ab}$	$93.48{\pm}0.62^{a}$

Values are the mean± standard deviation of 3 replicates; values with different superscripts in a row are significantly different ($p < 0.05$); AV: acid value (mg KOH/g); PV: peroxide value (mEq. O_2/Kg); RI: refractive index; IV: iodine value/number.

Acid value was in the range of range 2.30 to 4.07 (mg KOH/g). Sesim III recorded the highest AV while Sesim I and Sesim II recorded the lowest values. Sesim III had a significantly different higher AV when compared with other sesame types. The oil extracted from the landrace and improved sesame seeds had AV within range specified for cold pressed and virgin oils (CODEX-STANDARD-210., 1999).

Peroxide value ranged from 4.0 to 6.0 mEq. O_2/Kg with Sesim I and Sesim II registering the highest and Sesim III lowest values. There was no significantly different in PV of oils from the different sesame types except for Sesim III and *Ajimo* which had significantly low PV. Peroxide value specifies the content of peroxides as active oxygen in a substance. A low PV as observed in this study suggests that sesame seed oil is relatively stable towards peroxidation (Gharby *et al*., 2015). According to CODEX-STAN 210, the acceptable maximum level of cold pressed and virgin oils is 15 mEq. O_2/Kg oil.

The IV of the oil ranged from 85.09 to 94.57. *Arut* had the highest IV while Sesim III had the lowest. Sesim III had a significantly low IV. Iodine value provides an effectual means of characterizing vegetable oils (Endo, 2018). Oils that are rich in SFA show low IV, while oils rich in UFA show high IV (Uddin *et al.*, 2021). Oils rich in MUFA (18:1ω9) have an IV in the range of 75 to 90, while those rich in PUFA (18:2ω6) have IV in the range of 120 to140 (Endo, 2018).

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

The objective of the study was to evaluate the proximate, mineral and fatty acid-composition and quality of the oil obtained from landrace and improved sesame seeds grown in Uganda. Proximate mineral and fatty acids composition were determined by AOAC methods. The oil quality parameters were determined by AOCS and AOAC methods. Generally, the findings from this study showed that there was variations in proximate, mineral and fatty acid-composition and quality of the oil obtained between the landrace and improved sesame seeds.

5.2 Conclusions

The seeds of landrace and improved sesame grown in Uganda are a good source of total fat, protein and crude fiber. Sesame oil is of good quality and contains sufficient amounts of PUFA that contributes to the healthy aspects of the oil. The major FA in the oil were C16:0, C18:0, C18:1ω9 and C18:2ω6 but unsaturated FA predominated over the SFA. Sesame is also a good source of the minerals; P, Mg, Fe, Zn and Cu. The oil had a favorable PUFA/SFA ratio but the ω6/ω3 was far from optimal. Sesame seed has a good balance between sodium and potassium with Na/K ratio of < 1 implying that regular consumption of sesame upon blending with seeds high in ω3 FA will contribute to good health.

5.3 Recommendations

1. Improved sesame seeds are preferred for oil production because of their greater oil content, which benefits the food and pharmaceutical industries.

2. The nutritional value of food products should be increased by choosing improved sesame seeds because they have a higher protein content than landraces.
3. Since landraces contain more polyunsaturated fatty acids (PUFA) than improved sesame seeds, they are good for making nutritious dietary oils.
4. Sesame oils should be blended with oils high in ω3 fatty acids, such as chia seed oil, to increase nutrition quality.

Further research is recommended in respect of profiling the amino acids of sesame protein with the view of establishing the protein quality.

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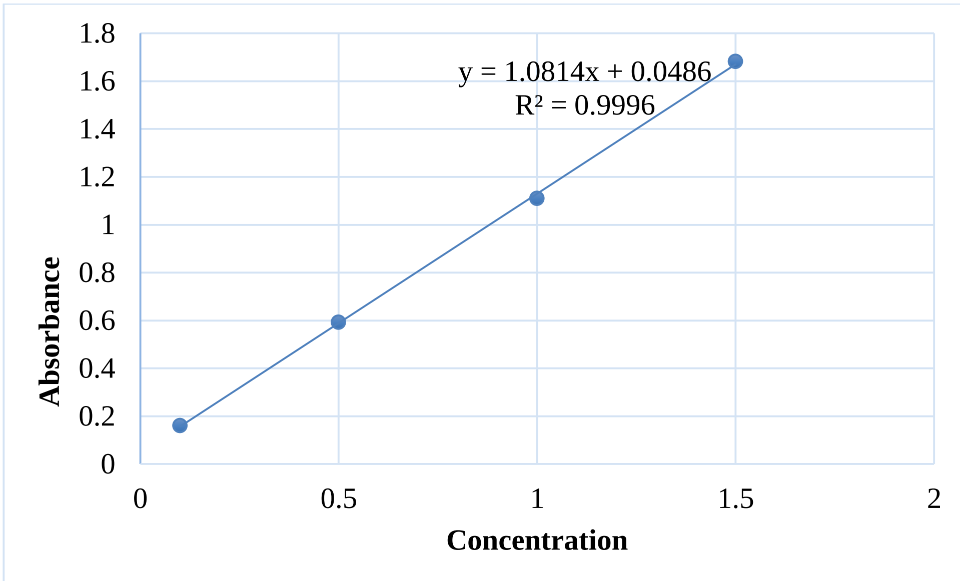
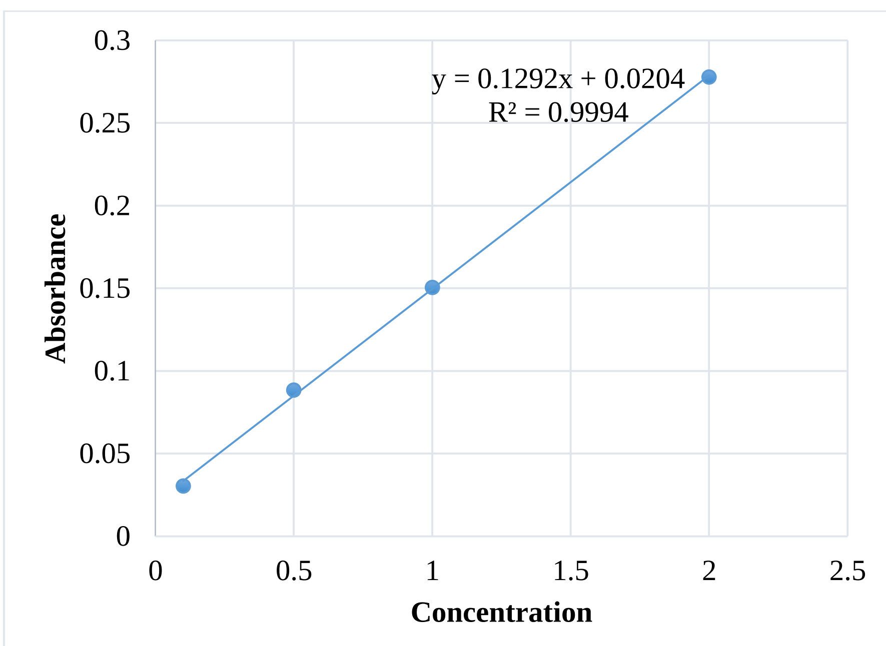
APPENDICES

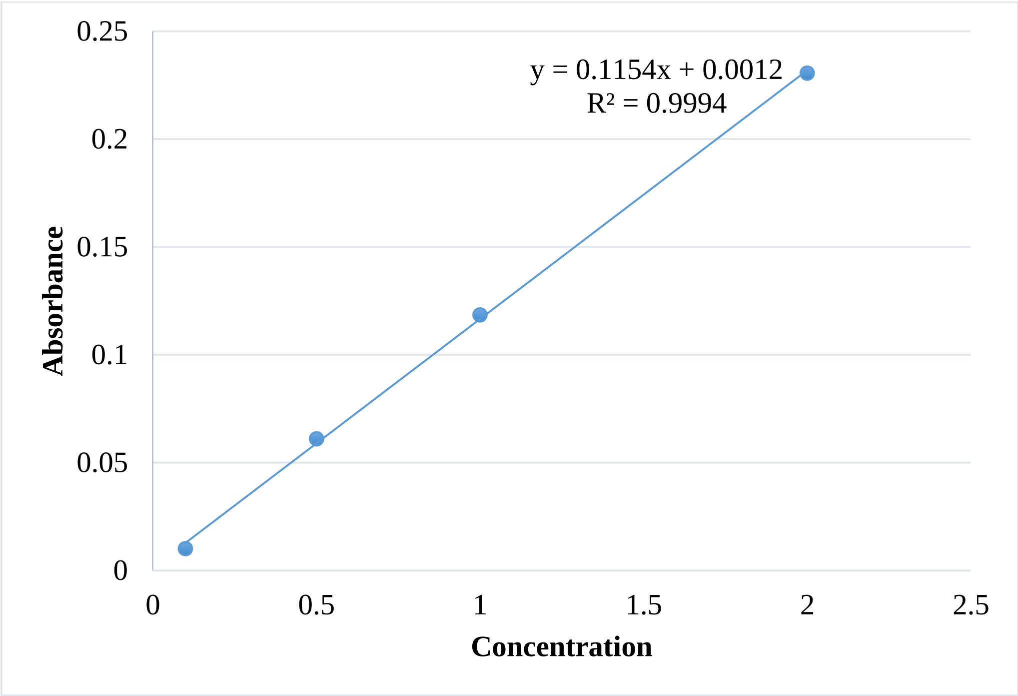
Appendix 1: Standard curve of absorbance verses concentration used in the determination of magnesium.



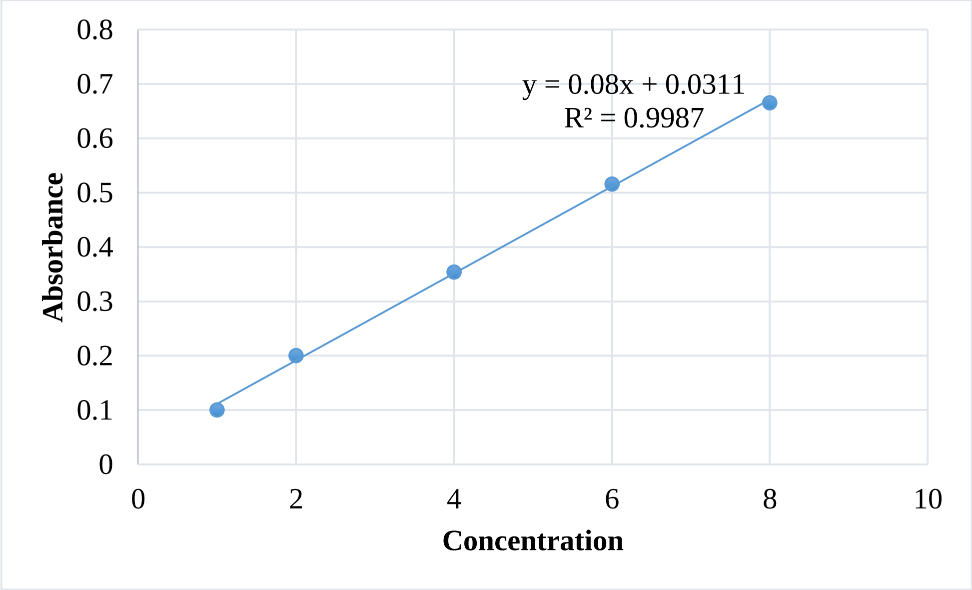
Appendix 2: Standard curve of absorbance verses concentration used in the determination of zinc.



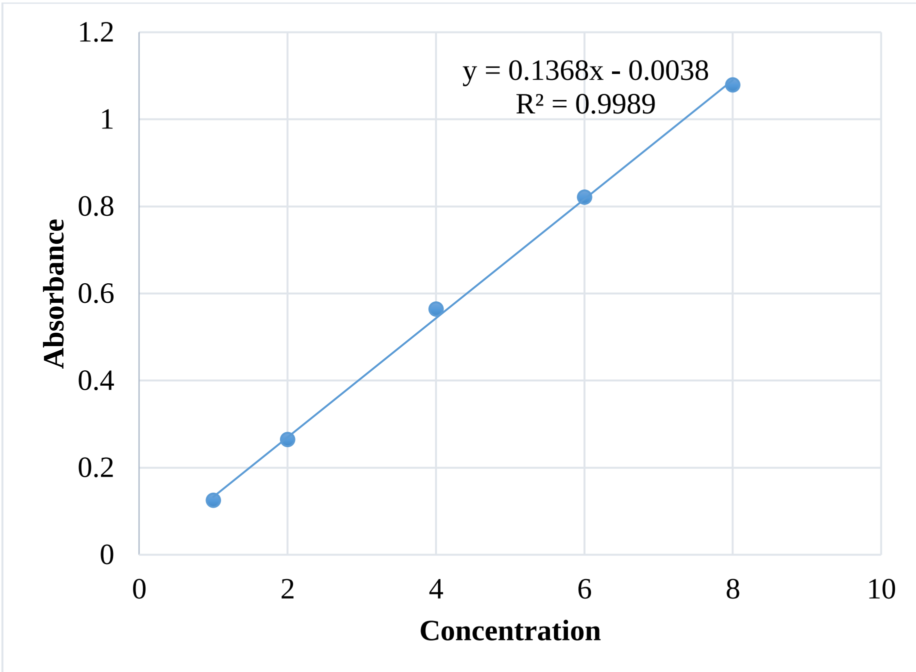
Appendix 3: Standard curve of absorbance verses concentration used in the determination of copper.



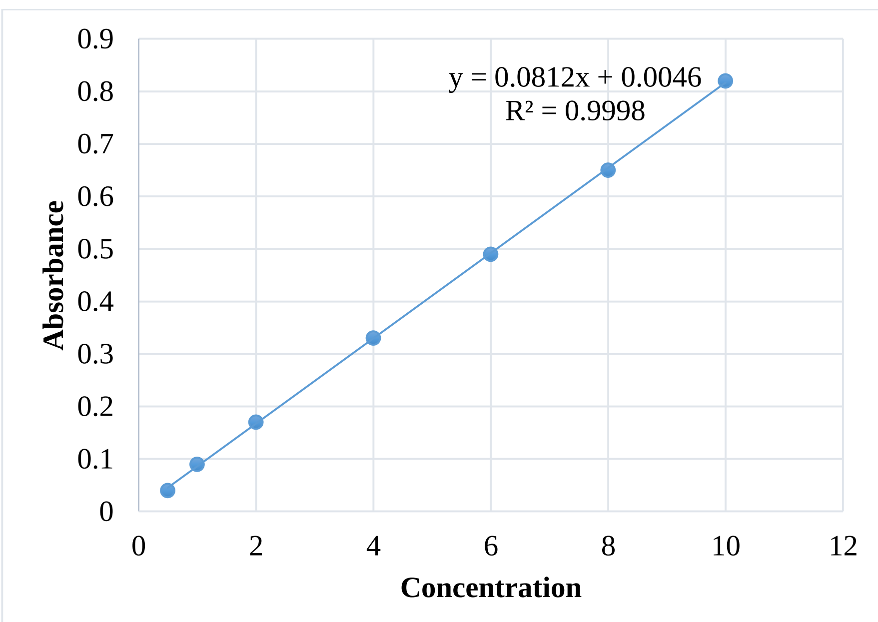
Appendix 4: Standard curve of absorbance verses concentration used in the determination of potassium.



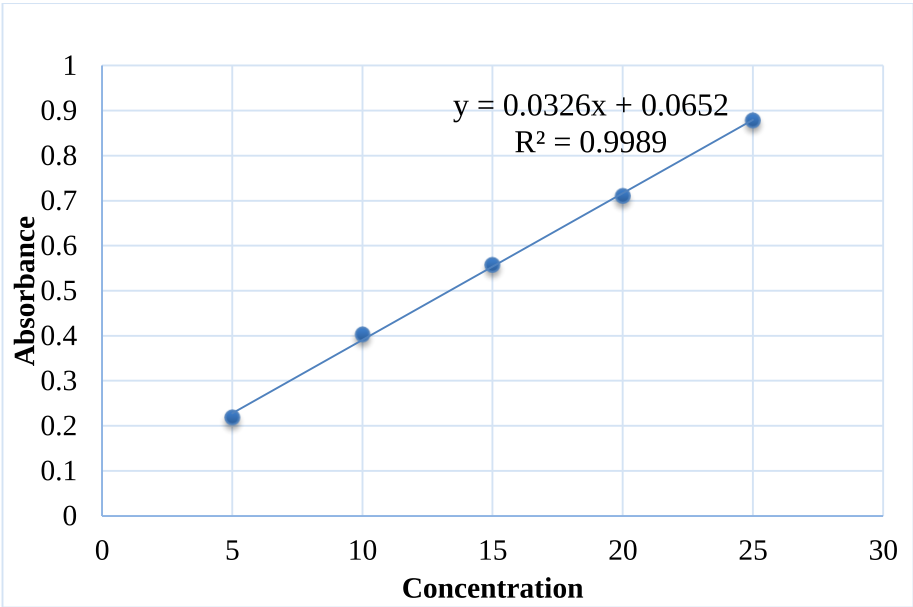
Appendix 5: Standard curve of absorbance verses concentration used in the determination of sodium.



Appendix 6: Standard curve of absorbance verses concentration used in the determination of phosphorus.



Appendix 7: Standard curve of absorbance verses concentration used in the determination of calcium.



Appendix 8: Standard curve of absorbance verses concentration used in the determination of iron.